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Li, Xiyan; Yin, Chungun

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DEPARTMENT OF ENERGY TECHNOLOGY  
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# TOWARDS A COMPREHENSIVE BIOMASS PARTICLE GASIFICATION MODEL

Xiyan Li, Chungun Yin

Department of Energy Technology, Aalborg University, Pontoppidanstraede 111, 9220 Aalborg East, Denmark

Email: xli@et.aau.dk

## 1 Introduction

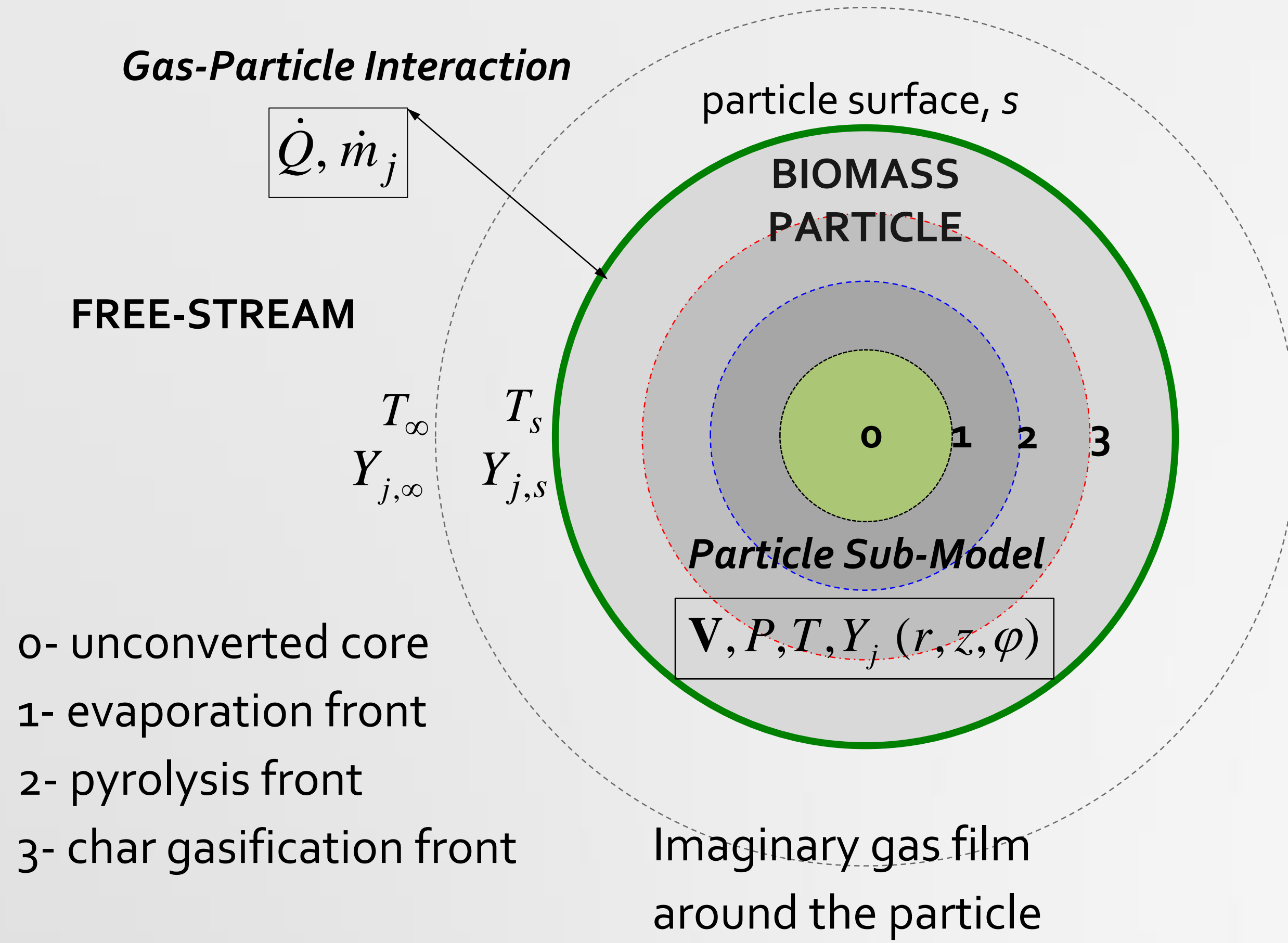


Figure 1 A conceptual view of the interaction of a large biomass particle with ambient flow and its conversion.

Figure 1 shows the geometry of a single biomass pellet. It is composed by solid biomass particle, imaginary gas film around the particle and atmosphere. Among them, the solid pellet is divided into a few grids. At each grid point, the velocity, gas pressure, temperature and species and so on are supposed to be calculated. Because at each time point, all the reactions (evaporation, pyrolysis, gasification) happens to all the grid points, order 0 – 3 can also be reversed.

## 2. Governing equations and flow chart

### For solid control volume

$$\text{For species equations} \quad \frac{\partial}{\partial t}(\epsilon \rho_g Y_j) + \text{div}(\rho_g \vec{u} Y_j) = \text{div}(\rho_g D_{j,m} \nabla Y_j) + S_{Y,j}$$

$$\begin{aligned} \text{For Energy equations} \quad & \frac{\partial}{\partial t} \left( \sum_{s,i} \rho_i h_i + \sum_{l,k} \rho_k h_k + \rho_g h_{mix} \right) + \text{div}(\rho_g \vec{u} h) \\ & = \text{div}(k_{eff} \nabla T) + \text{div} \left( \sum_j h_j \rho_g D_{j,m} \nabla Y_j \right) + S_h \end{aligned}$$

$$\text{For Continuity equations} \quad \frac{\partial}{\partial t}(\epsilon \rho_g) + \text{div}(\rho_g \vec{u}) = S_g$$

A typical discretized form PDEs using central differential method and fully implicit scheme is as shown below.

$$a_p \phi_p = a_w \phi_w + a_e \phi_e + a_p^0 \phi_p^0 + b$$

### For ambient flow

$$D_{j,m} A_s \left. \frac{\partial Y_{i(j,k)}}{\partial r} \right|_{r=r_p} = h_m A_s (Y_{i(j,k),\infty} - Y_{i(j,k),s})$$

$$k_{eff} A_s \left. \frac{\partial T}{\partial r} \right|_{r=r_p} = h_T A_s (T_f - T) + A_s \omega \sigma (T_w^4 - T^4)$$

$$Nu \equiv \frac{h_T L_c}{k_g} = 2.0 + 0.6 Re^{1/2} Pr^{1/3}$$

$$Sh \equiv \frac{h_m L_c}{D_g} = 2.0 + 0.6 Re^{1/2} Sc^{1/3}$$

$$T_{ref} = T_s + 1/3 (T_\infty - T_s)$$

$$Y_{j,ref} = T_{j,s} + 1/3 (T_{j,\infty} - T_{j,s})$$

### For size changing

$$\begin{aligned} \theta &= V_P / V_{p,0} = (d_p)^3 / (d_{p,0})^3 \\ &= 1 + (1 - \theta_m) \left( \frac{\rho_m}{\rho_{m,0}} - 1 \right) + \theta_m (1 - \theta_v) \left( \frac{\rho_m}{\rho_{m,0}} - 1 \right) + \theta_m \theta_v (1 - \theta_c) \left( \frac{\rho_c}{\rho_{c,0}} - 1 \right) \end{aligned}$$

**ABSTRACT:** In within a generic particle framework, assuming the feed is a woody biomass pellet. this paper, a comprehensive mathematical model for biomass particle gasification is developed. All the key processes, e.g., moisture evaporation, pyrolysis, heterogeneous char reactions, intra-particle heat and mass transfer, and changes in thermophysical properties and so on will be calculated by CFD.

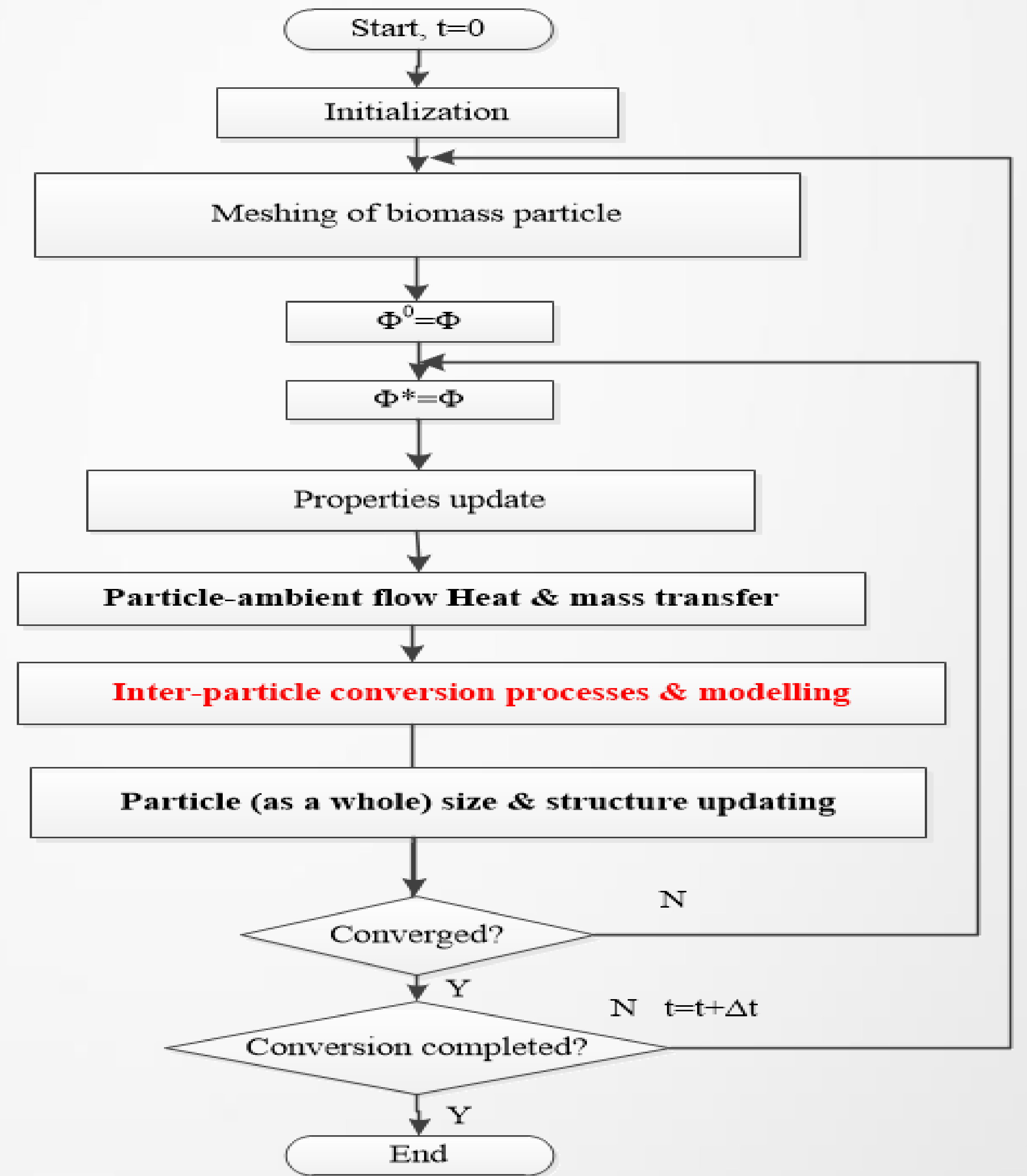


Figure 2 Flow chart within all the key issues to be solved

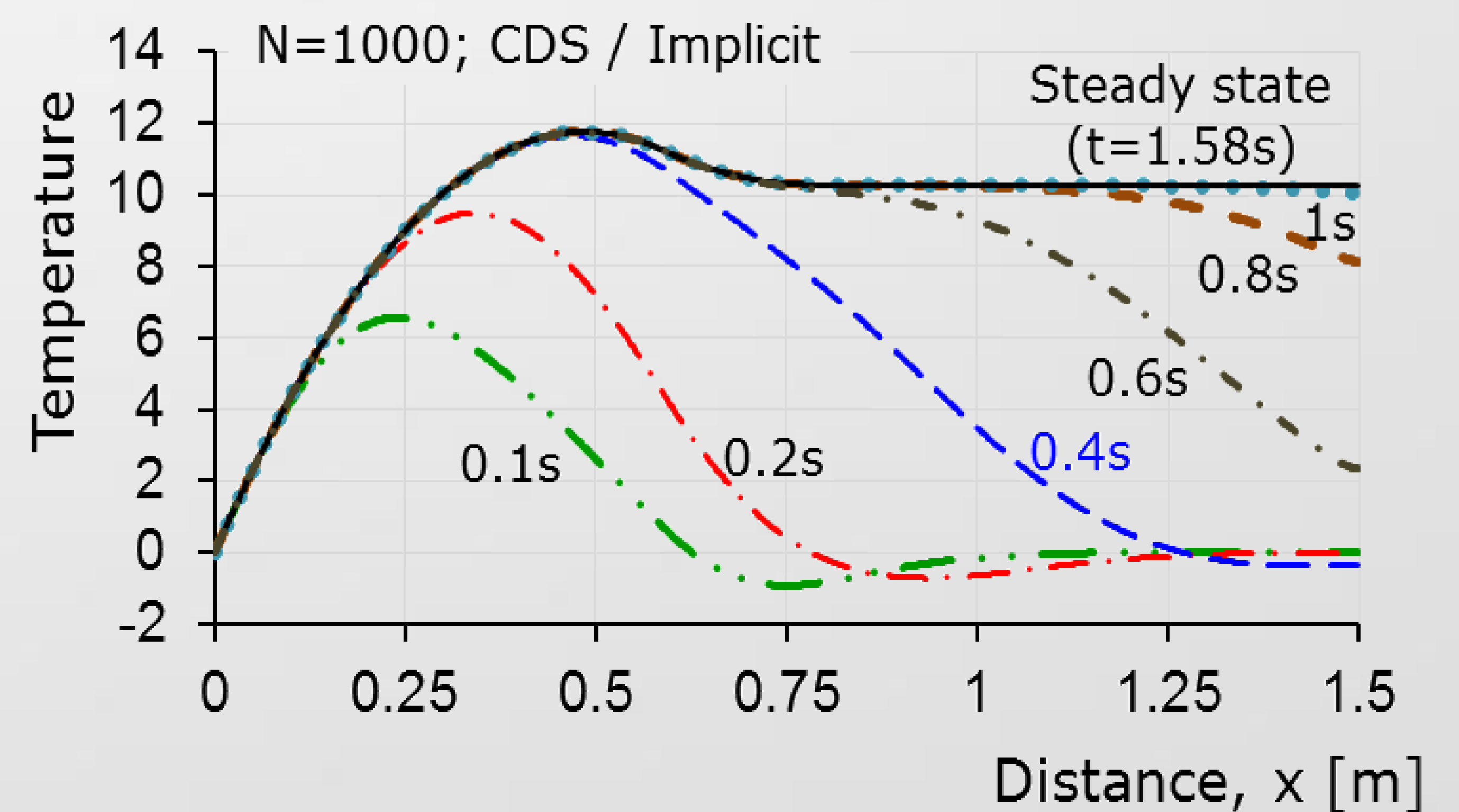


Figure 3 Comparison of analytical solution and numerical solution based on a simple case

## 3. Conclusions

- (1) A relatively integral mathematical model is given in this paper. All the twenty one chemical reactions and their reaction rates are given. The key transport equations of a single biomass pellet during gasification is presented.
- (2) Highly overlapping between an analytical solution and a stable state of numerical solution certify the possibility of using central differential scheme to solve complete mathematical questions.